THE INFLUENCE OF BREED, SIRE AND TYPE OF BIRTH AND REARING ON THE WEANING WEIGHT OF EWE LAMBS

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INTRODUCTION

The total sheep population of Canada has increased slightly during the past sixty-five years, from 3,048,678 in 1881 to 3,378,000 in 1946. The increase in Western Canada has been many times that in the Dominion as a whole. The total sheep population of the territories, which later formed the provinces of Alberta and Saskatchewan, was 346 in 1881. By 1946 this had increased to 1,415,000. This great increase in the west has resulted from a translocation of the sheep raising industry due to the development of sheep ranching. Sheep ranching has become an important industry which utilizes to the best advantage the marginal lands of our drier and otherwise untillable areas in Western Canada.

The course of its development has not been one of constant progress. Many factors, such as the advance of intensive agriculture early in the present century and the depression of more recent years, have caused temporary lulls in the growth of the industry. At the present time, following a rapid increase during the war years, the sheep

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INTRODUCTION

population is on the decline due to high costs of production and the attractiveness of other farm enterprises. Throughout all these periods of crisis the key to the problem has been efficiency of production, and, if this important industry is to survive and flourish again, the sheepmen of Western Canada must look once more to methods of increasing their efficiency of production.

One method of increasing efficiency is a clearer understanding or evaluation of the various factors that affect the weaning weight of lambs, and the utilization of this knowledge in the selection of ewe lambs for replacement stock, or sires for the breeding flock.

The weaning weight of lambs is determined by many factors. Some are largely environmental, some are largely hereditary in origin, but few are entirely one or the other. Therefore, it is the combined effect or the interaction of environment and heredity that is displayed in weaning weight.

The environmental conditions to which the lambs in any one flock are subjected in any year are reasonably similar for all lambs. Therefore, the variability in weaning weights in any flock is due mainly to hereditary factors (differing in each individual) and their reaction to the particular environment prevailing in that year.

Since the selection of lambs as replacement stock, or the comparison of progeny groups at weaning age, is carried out within flocks much of the error in such a selection or comparison is due to an incorrect evaluation of the hereditary factors affecting weaning weight.

It can be seen readily that a twin lamb reared as a twin, in constant competition with its mate for prenatal and post-natal nutrients, has a lesser chance for rapid growth and development than a single lamb that has no competition for the nutrients that it requires. Similarly, a lamb born early in the lambing season should be heavier than a lamb born late in the season when both are weaned on a common date, and a lamb that has an abundant milk supply stands a better chance for survival, growth, and development than one that has only an average milk supply. Generally, these advantages show their maximum effect during the first few months of life and lessen with increasing age until maturity is reached. Selection of lambs for replacement stock at weaning time tends to favor those lambs that have had the benefit of these temporary advantages during their early development. Thus, some lambs are culled at weaning time which actually may be potentially superior to some of the lambs selected for replacements because no satisfactory method of evaluating the factors affecting weaning weight

has been developed.

Thus the selection of replacement females and the comparison of progeny groups is biased through the lack of an adequate method of evaluating the factors affecting weaning weights. It is true that to a limited extent experience of the person making such selections and comparisons reduces this bias, but, until some method of evaluating these factors can be developed, some of the better lambs will be culled and some of the poorer lambs will be retained for breeding purposes. Similarly, in progeny group comparisons some of the better sires, handicapped by a high proportion of twin lambs in certain years, may be withdrawn from service in favor of some of the poorer sires that have received the benefit of a high proportion of single lambs.

So that an evaluation could be placed on some of the factors influencing weaning weight, and some progress could be made toward correcting the bias in selection and progeny comparison, a study was made of the influence of breed, sire, and type of birth and rearing on the weaning weight of ewe lambs using data from the flock at the Experimental Station, Lethbridge.

REVIEW OF LITERATURE

The literature on the various phases of the sheep industry is extensive, but in the field of growth rate and factors affecting weaning weight it is limited, and in the main pertaining to mutton sheep. One of the earlier studies was made by Hammond (3). In 1921 he reported the growth rate in lambs of different breeds of sheep. His work indicated, (a) that the growth rate in lambs during the first nine months was three times as great as during the subsequent twelve months, (b) that differences in growth rate were primarily breed differences, (c) that factors that prohibited satisfactory growth during the first year showed a detrimental effect on mature size and weight. This work on growth rate was substantiated by Foster (2) in the United States, who stated that lambs maintained a relatively rapid rate of growth from birth to twenty weeks of age. At this age he noted a sharp decline that subsequently was followed by a less rapid rate of growth.

In a later publication Hammond (4) found that differences in the weights of Suffolk lambs at five months of age were attributable to sex, type of birth, type of rearing, time of birth in respect to the date on which lambing commenced, dam, sire, and post-natal care.

This author established correlations between, (a) weight of lambs at twenty weeks and one week of age, (b) weight of lambs at sixty-one weeks and one week of age, and (c) weight of lambs at sixty-one weeks and twenty weeks of age.

Yearling measurements appear to have a useful predictive value for lifetime merit according to Terrill (11). He reported highly significant correlations between weaning weight and average lifetime weight of 0.46; between yearling weight and average lifetime weight of 0.54; between October weight of yearlings (approximately 18 months) and average lifetime weight of 0.68. The corresponding regressions of early measurement on the lifetime average were 0.53, 0.51, and 0.72 respectively. These data indicate that weaning weight would also have a useful predictive value for lifetime body weight.

The paucity of information on the growth rates of the various classes of livestock was emphasized by Phillips, Stoehr, and Brier (9) in reporting a study on the growth rate of single and twin lambs of both sexes from birth to yearling age. They found that both sexes maintained relatively constant rates of rapid growth to the age of 25 weeks. At this time both sexes suffered a temporary setback from which the males recovered much more satisfactorily than the females.

These authors postulated that this failure of ewe lambs to continue rapid growth after weaning was due to unsatisfactory nutrition and emphasized the need for supplying ewe lambs with adequate feed.

Phillips and Dawson (8) visualized the entire problem when they considered the factors affecting survival, growth, and selection of lambs. Their work was confined to three of the mutton breeds of sheep yet the principles which they evolved have an application in the range breeds of sheep as well. Survival rate was based on the proportion of the various groups that were present at three months of age. In the relation of birth factors to selection of breeding animals they found that in five out of six groups a higher proportion of single lambs than of twin lambs was retained. This difference was highly significant in one group, on the borderline of significance in three groups, and insignificant in the others. Thus they postulated a distinct tendency to favor single lambs over twin lambs in selection. This tendency was undesirable as weight advantages due to type of birth were temporary ones that show maximum effect early in life and tend to disappear as maturity is approached. In a similar manner these authors found that early lambs were favored over late lambs and heavier lambs at birth were favored over lighter lambs at birth. These favoritisms were based on methods of visual selection and as a re-

sult it can be seen that it is the effect of these factors on weaning weight that is the important point in these discrepancies in selection. These authors stated that from the genetic standpoint this result reduces the chances of selecting animals that are superior in mutton form since there is no reason to assume that any one of these groups should have more desirable genes for mutton qualities than any other comparable group.

A study of the factors affecting weanling traits of Rambouillet lambs was reported by Hazel and Terrill (5), in 1945. They found that sex, age of dam, type of birth, age at weaning, and percentage inbreeding accounted for 8.9, 3.1, 12.2, 5.1, and 6.4 per cent respectively of the total variation in weaning weight of range Rambouillet lambs. These authors pointed out that many other factors of less tangible or measurable character, such as parasitism, dams with spoiled udders, and errors in scoring undoubtedly affected some weanling traits.

The following year the same authors reported a similar study (6) on Columbia, Corriedale, and Targhee lambs. Their results indicated that sex, age of dam, type of birth, age at weaning, degree of inbreeding, and breed all were highly significant in their effect on the weaning

weight of lambs. The authors suggest a restriction on the progress in animal improvement through selection because only part of the variation in most traits is caused by genetic differences. Variation caused by environment may be partially adjusted if the effect of some factors of environment can be measured. Thus the animal breeder can increase progress insofar as he can compensate for the effects of known inequalities in environment.

Hazel and Terrill (7), in a paper of which the abstract only has been procured by the writer, described the final phase of this study. This paper dealt with the construction and use of a selection index for range Rambouillet lambs. Standard partial regression coefficients reflecting the relative economic importance of the various traits were stated as follows: face covering, 0.403; neck folds, 0.392; body weight, 0.379; condition, 0.155; staple length, 0.142; body type, 0.009. The index method of selection was used in 1945 and was compared to the method of visual selection applied in previous years. The ratio of the selection differentials for the lambs saved in 1945 to those saved in 1944 were as follows for ram and ewe lambs respectively: face covering, 1.14 and 1.80; staple length, 1.12 and 2.25; body weight, 1.19 and 2.44; body type, 1.02 and 1.69; condition, 0.81 and 2.75; neck folds, 0.77 and 0.50.

These figures show that the index was only slightly more efficient than visual selection for ram lambs, where only a small proportion of the lambs was kept, but was considerably more efficient for ewe lambs where a large proportion of the lambs was kept. It also was evident that the index was less efficient than visual selection for the trait, neck folds. The chief advantages of the index claimed by the authors were its emphasis on highly heritable and economically important characters and its provision of a constant and objective basis for comparing individuals. Its disadvantages lay in the laborious calculations involved and the necessity of culling for such characters as hairiness in the fleece independent of the index.

Previous literature indicates that breed, sire, and type of birth and rearing each exert influences in varying degrees on the weaning weight of lambs. Due to these influences selection tends to favor singles over twins, and as a result this selection tends toward lowered fertility in future flocks. Similar favoritisms existed for lambs born early in the lambing season and lambs that were heavy at birth.

At the time this study was undertaken the amount of material published on this phase of the sheep industry was limited and none was directly applicable to the environmental conditions in this country. The work of Hazel and Terrill

(5, 6, and 7) carried out at Dubois, Idaho, most nearly approaches the conditions in this country and it is expected that the results of this study will be similar to those obtained by these workers.

MATERIALS AND METHODS

The weaning weight data analysed in this study have been recorded on the flock at the Dominion Experimental Station, Lethbridge, Alberta, over a seven year period, 1938 to 1946, excluding 1943 and 1944. The data were collected on 1,116 ewe lambs of three breeds, namely, New Zealand Corriedale, Canadian Corriedale, and Rambouillet, which were born during that seven year period.

The New Zealand Corriedales have been maintained in small numbers in the flock as a pure breed. Their purpose has been to supply foundation males for crossbreeding and to serve as a comparison group for the resulting crossbred sheep.

The Rambouillets have been maintained in larger numbers, also as a pure breed. Their purpose has been to supply the foundation females for crossbreeding work and to serve as a control group for comparing crossbred and other breeds of sheep under range conditions.

The Canadian Corriedales constitute a new breed of sheep that has been developed at the Experimental Station. Their number, while considerably larger than the New Zealand Corriedales, is about half that of the Rambouillets.

In the development of the Canadian Corriedales Lincoln x Rambouillet crossbred ewes were used as the foundation females, and these ewes were topped with New Zealand Corriedale rams. The first cross was made in 1919 and imported Corriedale rams were used on the crossbred ewes and subsequent progeny in a grading-up program. This was continued until 1933 when the flock was closed and selected males and females within the flock have been inbred in an attempt to establish a type deemed to be desirable. Thus, a new breed has been developed which is somewhat intermediate between the New Zealand Corriedales and the Rambouillet in mutton conformation, size, and wool characteristics.

In managerial practices the three breeds have been treated alike and within years subjected to the same environment. During the five year period, 1938 to 1942 inclusive, the ewe band was maintained under semi-farm and semi-range conditions. The band was lambed in April and early May, each ewe being placed in a claiming pen with her offspring as they were dropped. The lambs were weighed, graded, and ear-tagged within 24 hours of birth, then moved into larger pens where they were held for a day or two until the ewes became thoroughly accustomed to their lambs. As each larger pen filled the groups were moved out and held for approximately ten days, when the lambs were docked and castrated. The band usually was sheared about the middle of May and dipped ten days to two weeks later.

At the end of May the ewe band, with their lambs at foot, was trailed across country about 100 miles to their summer range in the forest reserve north of Bellevue, in the Rocky Mountains. The band remained there until the last week of September. At that time the trail across country was commenced so that the band would arrive at the Station early in October. On arrival at the Experimental Station the ewe band was placed on pasture and stubble fields until the ewes were placed in the breeding pens about the middle of November. They remained in the breeding pens for six weeks and for the remainder of the year were fed, or grazed out as conditions permitted.

When the band returned from the summer range the lambs were weaned, weighed, and graded by experienced animal husbandmen. By the combination of these weights and grading the ewe lambs for replacement stock were selected. The records at this point were carried forward to include the age in days and the average daily gain for each lamb from birth to weaning. Thus the records on each lamb contained date of birth, type of birth, sex, tag number, birth weight, birth grade, weaning weight, age at weaning, and average daily gain from birth to weaning.

In 1943 a tract of land was obtained on the Bow River at Scandia to be used as a sheep ranch where the flock could be maintained under range conditions the year

round. The flock was moved to the Scandia Ranch after lambing and shearing in 1943 but due to inadequate facilities, weaning weights could not be obtained for the two years 1943 and 1944. However, in 1945 a set of scales was installed and once more complete records were secured. In general, managerial practices remained similar to those detailed above. It should be noted that 1945 was a very rigorous year as far as the lamb crop was concerned, for good spring grazing was difficult to obtain. This, in conjunction with a cold wet spring followed by a dry summer, resulted in very poor growth and development which shows up so clearly in the data for that year.

The raw data were compiled under three main classes within breed and year, namely, singles, twins raised singly, and twins raised as twins. These three main classes were then subdivided into sire groups so that the 1,116 ewe lambs were divided into breed, year, type of birth and rearing, and sire groups. A summary of the numbers and the mean weight of individuals in each subgroup appears in Tables 1A, 1B, and 1C.

Table IA

Number and Mean Weight at Weaning of New Zealand Corriedale Lambs in Subgroups

Year	Coded Sire No.[1]	Singly		Twins Raised Singly		Twins Raised Twin	
		No.	Mean Weight lbs.	No.	Mean Weight lbs.	No.	Mean Weight lbs.
1938	1N	8	58.0	3	61.7	1	45.0
1939	1N	14	60.4	1	58.0	2	59.0
1940	1N	13	54.4	3	64.3	0	-
1941	2N	6	68.5	3	63.0	0	-
1942	2N	11	68.7	1	71.0	0	-
1945	3N	9	54.3	1	65.0	0	-
1946	3N	18	68.2	1	71.0	0	-
Breed Total and Average		79	62.0	13	64.0	3	54.3

[1]Coded sire numbers have been used to facilitate tabulation

Table IB

Number and Mean Weight at Weaning of Canadian Corriedale Lambs in Subgroups

Year	Coded Sire No.[1]	Singly		Twins Raised Singly		Twins Raised Twin	
		No.	Mean Weight lbs.	No.	Mean Weight lbs.	No.	Mean Weight lbs.
1938	1C	6	58.2	7	65.8	0	-
	2C	4	64.8	11	66.4	0	-
	3C	6	66.8	6	64.3	0	-
	4C	6	58.7	5	62.0	1	45.0
Year Total		22	61.9	29	65.1	1	45.0
1939	1C	12	67.8	6	66.0	6	56.2
	5C	8	72.2	3	77.7	1	64.0
	3C	9	77.3	5	84.4	7	66.4
	4C	11	60.9	3	77.7	0	-
Year Total		40	69.0	17	75.5	14	61.8
1940	1C	10	63.0	0	-	5	50.2
	3C	12	70.2	3	67.0	5	53.4
	6C	5	61.5	6	64.2	2	58.0
	4C	9	58.9	1	63.0	2	51.0
Year Total		36	64.2	10	64.9	14	52.6
1941	1C	3	75.0	1	77.0	10	63.1
	6C	4	76.2	5	68.2	9	60.7
	3C	9	69.4	2	74.0	3	67.3
	7C	7	62.8	2	64.0	3	58.7
Year Total		23	69.3	10	69.4	25	62.2
1942	8C	6	66.5	10	67.6	4	65.5
	9C	4	74.2	4	79.0	7	65.4
	10C	6	72.8	1	68.0	4	72.2
	11C	8	60.6	5	72.6	1	49.0
Year Total		24	67.4	20	71.2	16	66.1
1945	12C	8	48.5	4	54.8	3	50.7
	13C	5	54.4	6	62.0	3	49.0
	14C	4	56.0	3	63.7	0	-
	15C	3	44.0	1	55.0	2	43.5
Year Total		20	50.8	14	59.8	8	48.2
1946	16C	8	67.5	3	69.7	3	57.3
	13C	10	68.8	6	73.0	4	66.5
	17C	2	65.5	1	69.0	1	51.0
	18C	7	62.7	1	62.0	1	56.0
Year Total		27	66.6	11	70.7	9	60.6
Breed Total		192	64.9	111	68.0	87	59.7

[1] Coded sire numbers have been used to facilitate tabulation

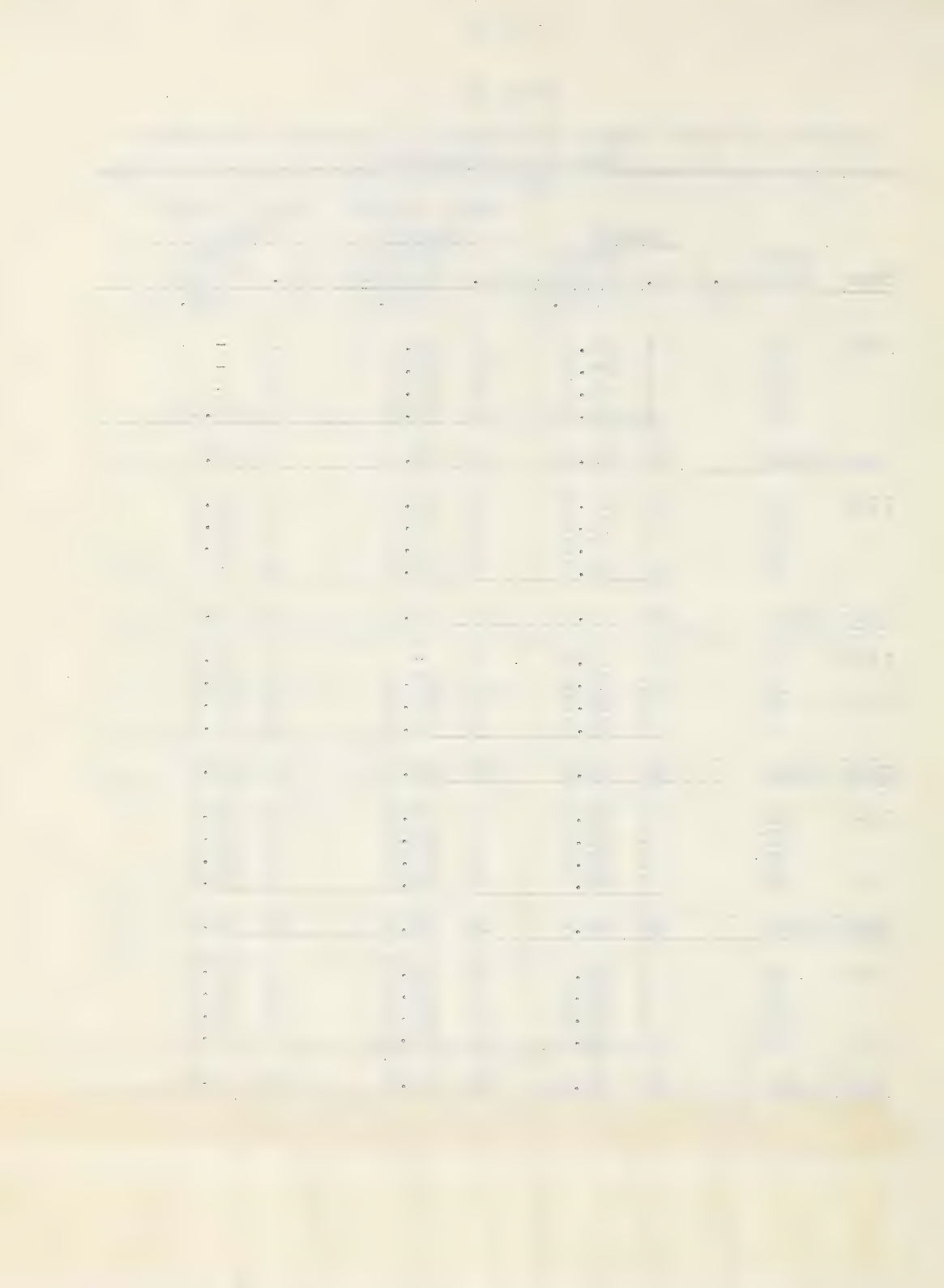
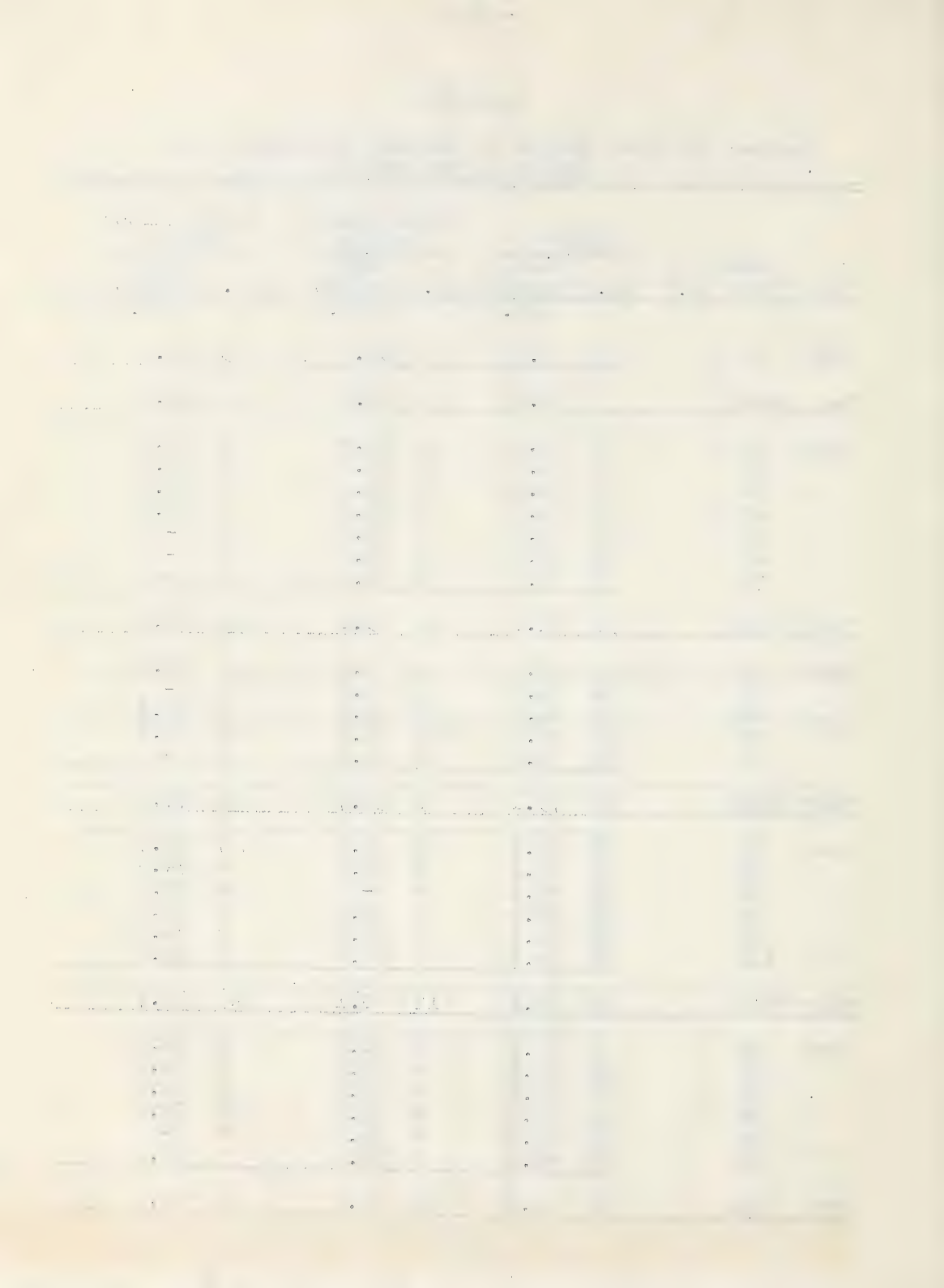


Table IC

Number and Mean Weight at Weaning of Rambouillet Lambs in Subgroups

Year	Coded Sire No.[1]	Singly		Twins Raised Singly		Twins Raised Twin	
		No.	Mean Weight lbs.	No.	Mean Weight lbs.	No.	Mean Weight lbs.
1938	1R	5	73.8	6	68.8	3	66.0
Year Total		5	73.8	6	68.8	3	66.0
1939	1R	8	72.1	2	67.5	6	76.0
	2R	6	72.3	1	76.0	2	72.0
	3R	5	73.4	2	68.0	3	56.7
	4R	13	73.8	3	80.3	3	70.0
	5R	12	72.1	2	79.5	0	-
	6R	5	67.4	4	76.8	0	-
	7R	3	79.3	1	71.0	0	-
Year Total		52	72.6	15	75.0	14	70.0
1940	8R	13	77.2	1	70.0	3	74.3
	3R	14	69.6	1	78.0	0	-
	4R	5	71.8	3	72.0	3	65.3
	7R	15	79.9	2	78.5	2	72.0
	9R	10	74.6	2	75.5	0	-
Year Total		57	75.1	9	74.7	8	70.4
1941	8R	18	84.7	2	80.0	7	69.7
	3R	9	75.3	3	78.7	6	74.8
	4R	13	84.1	0	-	10	72.0
	7R	10	79.9	1	80.0	5	75.4
	9R	10	86.3	1	65.0	7	74.6
	10R	6	84.7	5	84.0	8	71.5
Year Total		66	82.8	12	80.1	43	72.7
1942	8R	9	88.8	6	81.5	5	77.8
	11R	12	82.1	4	78.5	7	70.1
	4R	8	84.8	4	77.8	4	72.8
	9R	12	85.3	4	82.0	8	72.1
	12R	3	82.3	4	74.5	0	-
	13R	3	90.0	3	84.3	3	75.0
Year Total		47	85.2	25	79.7	27	73.1
1945	14R	11	74.9	8	69.0	6	63.8
	15R	13	68.6	0	-	4	56.5
	16R	8	78.0	5	64.8	8	54.4
	17R	5	65.2	5	68.6	3	60.3
	18R	11	67.9	5	74.0	0	-
	19R	7	71.7	12	70.4	3	67.3
Year Total		55	71.2	35	69.5	24	59.4
1946	14R	14	78.2	3	83.7	3	79.3
	16R	11	87.1	4	81.2	5	72.2
	17R	16	78.9	1	78.0	6	72.0
	20R	19	82.2	4	79.8	4	74.5
	21R	12	85.7	7	85.8	5	73.6
	22R	11	82.6	0	-	3	76.3
Year Total		83	82.1	19	82.8	26	74.1
Breed Total		365	78.4	121	75.8	145	70.3

[1]Coded sire numbers have been used to facilitate tabulation



The disproportion of numbers in the subclasses was apparent in Tables 1A, 1B, and 1C but in only one group was it considered serious enough to disrupt the analytical procedure. In the New Zealand Corriedale twins raised twin there were only three lambs for the whole period of seven years. This group constituted only 1.3 per cent of the total lambs of this birth type and as a result this group could not be satisfactorily included in the analysis. This limited the general analysis of the data, but the withdrawal of this group allowed much useful information to be obtained from the other groups.

In the analysis of such data it was necessary to select a unit of measurement that could be used throughout as the basis of comparison. Two alternative measurements were available, namely, weaning weight in pounds, and average daily gain in pounds per day from birth to weaning. Although certain advantages were displayed by both, the accuracy of either measurement depended on reasonable equality in age for the lambs in different groups. Due to the facts that, 1. weaning weight is an actual not a calculated measurement, and 2. weaning weight not growth rate is the subject under consideration, it was deemed advisable to select weaning weight in pounds as the basis of comparison. Statistical procedure used on these data followed the methods outlined by Snedecor (10).

ANALYSIS OF DATA

Detailed summaries of the data on which this analysis is based are shown in Tables IA, IB, and IC. For ease of comparing the data for the three breeds involved in the study a summary of weaning weights and age at weaning is given in Table II.

Table II

Number, Mean Weight, and Average Age at Weaning of Ewe Lambs by Breeds and Type of Birth and Rearing

Breed	Type of Birth	No.	Mean Weight lbs.	Age in Days
N. Z. Corriedale	Single	79	62.0	174.5
	Twins Raised Singly	13	64.0	177.2
	Twins Raised Twin	3	54.3	174.0
Breed Total and Average		95	62.0	175.9
Can. Corriedale	Single	192	64.9	174.5
	Twins Raised Singly	111	68.0	172.1
	Twins Raised Twin	87	59.7	181.7
Breed Total and Average		390	64.6	175.4
Rambouillet	Single	365	78.4	173.4
	Twins Raised Singly	121	75.8	168.8
	Twins Raised Twin	145	70.3	175.7
Breed Total and Average		631	76.0	173.1
Total and Average All Breeds		1116	70.9	174.1

Detailed analysis of certain features of these data will be presented later but it seems important to draw attention to certain factors that have a direct bearing on the analysis. It is evident from the data that there were great differences in the number of animals involved in the three breed groups. These differences arose mainly out of the relative sizes of the breeding units within the whole flock. More disturbing is the fact that the proportion of the different types of birth and rearing was not the same in each breed group. For example, in the New Zealand Corriedales only 3.2 per cent of the lambs were born twins and raised as such whereas for the Canadian Corriedales and Rambouillets this class constituted 22.3 and 23.0 per cent respectively. For lambs born as twins and raised as singles the percentages were 13.7, 28.5, and 19.2 respectively for the three breeds. This disproportion of the number of individuals in subclasses has a direct influence on the analysis that will be made later.

The mean weights reported in Table II indicate that in comparing lambs of different birth types within breeds correction factors should be used. For example assuming that all the data in Table II was recorded on lambs born in one year, in comparing New Zealand Corriedales it may be advisable to correct the three types of birth to the breed average. Thus singles would require zero correction, twins

raised singly would be corrected by -2.0 pounds and twins raised twin would be corrected by +7.7 pounds. Similarly the correction factors for Canadian Corriedales would be -0.3, -3.4, and +3.9 pounds for singles, twins raised singly, and twins raised twin respectively, and the correction factors for Rambouillets would be -2.4, +0.2, and +5.7 pounds for singles, twins raised singly, and twins raised twin.

Analysis of Age in Days at Weaning

It was stated earlier that the decision had been reached to use average weaning weights rather than average daily gain in this analysis. To determine the accuracy of this decision an analysis of age at weaning is shown in Table III.

Table III

Analysis of Variance in Age at Weaning of Three Breeds of Lambs Within Type of Birth and Rearing

Variance due to	Singles		Twins Raised Singly		Twins Raised Twin	
	Degrees of Freedom	Mean Square	Degrees of Freedom	Mean Square	Degrees of Freedom	Mean Square
Breed	2	81.7	2	595.6	2	1019.2**
Error	633	154.9	242	213.8	232	165.0
Total	635		244		234	

**Significant beyond the 1% point

The analysis in Table III indicates that there was no significant difference between breeds in age at weaning for singles and for twins raised as singles but there was a highly significant difference between breeds in the average age of twins raised twins. As this latter group constituted the smallest proportion it was decided that the difference in age, amounting to a maximum of 7.7 days, and reduced to 6.0 days by the elimination of the New Zealand Corriedale twins raised twin, would not be a serious factor in affecting differences in actual weaning weights.

Analysis of Weaning Weight Variation

As the New Zealand Corriedale twins raised twins constituted such a small group (3.2 per cent for this breed and 1.3 per cent for this birth type) it was felt that this disproportion would affect the analysis seriously so this breed group was eliminated from the present analysis. The analysis of variance in weaning weight for the two remaining breeds, for three types of birth, for seven years is presented in Table IV.

Table IV

Analysis of Variance in Weaning Weight of Ewe Lambs of Three Types of Birth and Rearing over a Seven Year Period

Variance due to	Degrees of Freedom	Mean Square
Year	6	3,715.6**
Breed	1	31,558.8*
Type	2	4,549.0**
Year x Breed	6	46.7
Year x Type	12	420.1**
Breed x Type	2	591.2**
Error	991	97.6
Total	1020	

*Significant beyond the 5% point

**Significant beyond the 1% point

The difference due to the secondary interaction, year x breed x type of birth, was found to be negligible and was included in the error term. The primary interaction year x breed was not significant. This indicated that the two breeds reacted similarly to the environment encountered in different years. The two primary interactions, year x type of birth, and breed x type of birth, were both highly significant. Thus, it is evident that the three types of birth did not react to different yearly environments in the same manner. This interaction could be expected in view of the fact that twins raised twin or singly would be handicapped by birth factors and would be less able to overcome their handicaps in unfavorable seasons than they would in favorable seasons.

Similarly the two breeds did not perform similarly in the three types of birth and rearing. This interaction can be seen in Table II in that the twins raised singly in the Canadian Corriedale breed actually were heavier at weaning than singles while the reverse was true in the Rambouillet breed. This performance by the Canadian Corriedale lambs was difficult to explain as it was a direct contradiction of normal expectation and was opposed to the results obtained by Hazel and Terrill (5) and Phillips, Stoehr, and Brier (9). The most logical

explanation that could be made was that in some way there was a relationship between twinning and above-average milk production in this particular breed. This is in agreement with Bonsma (1) who attributes practically all weight difference at weaning to differences in milk production, and Hammond (4) who states that milk yield and fertility are often associated.

Since the interactions, year x type of birth and breed x type of birth, were highly significant these interactions were used as error in testing the significance of the main factors contributing to variance in weaning weight. Year x type of birth was used to test the significance of year and type differences. Breed x type of birth was used to test the significance of breed differences. The differences due to breed were significant and the difference due to years and type of birth were highly significant.

Analysis of Weaning Weight Variation in Single Lambs

Due to the extreme disproportion of the subclass numbers the New Zealand Corriedales could not be included in a general analysis of variance. However, in order to incorporate this third breed as fully as possible in the complete analysis an analysis of single

lambs, where the proportion of New Zealand Corriedales was satisfactory, was made. This analysis appears in Table V.

Table V

Analysis of Variance in Weaning Weight of Single Lambs of Three Breeds for a Seven Year Period

Variance due to	Degrees of Freedom	Mean Square
Breed	2	16,312.5**
Year	6	3,210.9**
Error	627	97.8
Total	635	

**Significant beyond the 1% point

In this analysis of variance in weaning weights of single lambs of all three breeds the interaction breed x year was found to be negligible and it was included in the error term. The differences due to breeds and years were highly significant. This was a normal expectancy as breed differences are well recognized, and these lamb groups were subjected to a great variety of environments in the seven year period.

Analysis of Weaning Weight Variation in Twin Lambs Raised Singly

The number of New Zealand Corriedale lambs in this group is just about on the border line of usefulness constituting approximately one tenth of the total number of lambs in this type of birth and rearing. The analysis of variance in weaning weight for twins raised singly for three breeds for a seven year period is presented in Table VI.

Table VI

Analysis of Variance in Weaning Weight of Twin Lambs Raised Singly for Three Breeds for a Seven Year Period

Variance due to	Degrees of Freedom	Mean Square
Breed	2	2,148.0**
Year	6	902.8**
Error	236	90.9
Total	244	

**Significant beyond the 1% point

In this analysis the interaction year x breed was found to be negligible and was included in the error term. The differences due to breed and year were again highly significant, indicating actual breed differences and actual year differences.

Analysis of Variance of Sire Differences Within Breed and Year on the Weaning Weight of Canadian Corriedale and Rambouillet Lambs

The size of the New Zealand Corriedale group in the flock under study required the use of only one sire each year. Accordingly, it was not possible to make a sire comparison within years for this breed. Any comparison made of New Zealand Corriedale sires would, in fact, involve a combined year and sire difference which could not be segregated into its component parts. The analysis of variance of sire differences within years and breeds is presented in Table VII.

Table VII

Analysis of Variance of Sire Differences in Canadian Corriedale and Rambouillet Lambs by Years

BREED - CANADIAN CORRIEDALE

Year	1938		1939		1940		1941	
Variance due to	DF	MSq	DF	MSq	DF	MSq	DF	MSq
Between Sire	3	136.6	3	605.3**	3	198.5	3	126.7
Within Sires	48	84.8	67	128.8	56	114.2	54	89.0

	1942		1945		1946	
Variance due to	DF	MSq	DF	MSq	DF	MSq
Between Sires	3	200.8	3	284.7	3	148.8
Within Sires	56	118.7	38	108.7	43	87.6

BREED - RAMBOUILLET

Year	1938		1939		1940		1941	
Variance due to	DF	MSq	DF	MSq	DF	MSq	DF	MSq
Between Sire	-	-	6	72.7	4	227.5*	5	59.6
Within Sires	-	-	74	140.4	69	77.9	115	117.4

	1942		1945		1946	
Variance due to	DF	MSq	DF	MSq	DF	MSq
Between Sires	5	100.7	5	116.9	5	110.2
Within Sires	93	111.2	108	115.3	122	101.0

*Significant beyond the 5% point

**Significant beyond the 1% point

The influence of sire in the two breeds considered accounted for significant differences in only two years. In 1939 in the Canadian Corriedales the difference due to sire was highly significant while in 1940 in the Rambouillets the sire difference was significant. In all other years the sire difference was not significant. This indicated that, where all sires used were representative of the breed, the differences which they caused in weaning weight were small. The findings of Hammond (4) are in agreement with this statement.

The Proportion of Total Variation Attributable to the Various Factors Under Consideration

The previous analyses have shown that for weaning weights significant differences exist between breeds, years, and types of birth and rearing, and that interactions between certain of these factors occur. This indicates that, in making selection of future breeding stock at weaning time, in making comparisons between progeny-groups, or in evaluating progress made in a breeding program, adjustments or corrections in individual weaning weights must be made to compensate for differences in these various factors. To permit practical application of the results obtained it was necessary to differentiate between the factors in terms of their importance. According to the method applied by

Hazel and Terrill (5) the percentage of the total variation equals the sums squares for any factor over the total sums squares x 100. The percentage of total variation then represents the importance of the contributing factor and the decision respecting the necessity for adjustment can be made.

The percentages of the total variation accounted for by breeds, years, and type of birth based on Tables IV, V, and VI are presented in Table VIII. The percentage of the total variation accounted for by sires, from Table VII, is presented in Table IX.

Table VIII

The Percentage of the Total Variation due to the Main Contributing Factors Breed, Year, and Type of Birth

Based on Table	III	IV	V
Contributing Factor	% of Total Variation	% of Total Variation	% of Total Variation
Breeds	18.96	28.81	13.78
Type of Birth and Rearing	5.47	-	-
Years	13.39	17.01	17.38

Table IX

Percentage of the Total Variation due to Sires in Canadian Corriedales and Rambouillets

Year	1938	1939	1940	1941	1942	1945	1946	Ave.
Breed								
Can. Corriedale	9.15	17.39	8.52	7.33	8.31	17.12	10.60	11.20
Rambouillet	-	4.03	14.48	2.16	4.64	4.49	4.28	5.68

In the two breeds, Canadian Corriedales and Rambouillets, breed, year, and birth type account for 37.82 per cent of the total variation in weaning weight. The percentage variation due to type of birth and rearing is somewhat smaller than that obtained by Hazel and Terrill (5) perhaps due to the unusual performance of the Canadian Corriedale twins raised singly.

In single lambs of the three breeds, breed and year account for 45.82 per cent of the total variation. This is considerably higher than the 31.16 per cent accounted for by these two factors in the twins raised singly of the three breeds.

The average sire difference in the Canadian Corriedale breed is approximately twice that in the Rambouillet. This would indicate that the Canadian Corriedale, being a new breed, has not reached the standard of uniformity attained in the Rambouillet which is a long established breed. Thus greater precaution must be taken in selecting Canadian Corriedale sires than Rambouillet sires.

GENERAL DISCUSSION

The results of the analyses of the effect of breed, sire, and type of birth and rearing on the weaning weight of ewe lambs indicated the presence of real differences attributable to the interaction of environment and heredity. Differences due to breed, year, and type of birth and rearing were significant or highly significant. Sire differences, on the whole, were not significant but did account for a sufficient portion of the total variation to warrant consideration in the comparison of progeny groups.

Breed differences were significant. They accounted for 18.96 per cent of the total variation in weaning weight when all types of birth and rearing were considered for the two major breeds, i.e. Canadian Corriedale and Rambouillet. When all three breeds were considered within type of birth, breed differences were highly significant, accounting for 28.81 and 13.78 per cent of the total variation in weaning weight for singles and twins raised singly respectively. Since selection of replacement stock in the flock under study was made within breeds the importance of breed differences in actual selection was not great, but the importance of breed differences lies in the fact that no correction factor can have universal usefulness for all breeds but individual corrections must be designed for each breed.

Year differences were highly significant in each analysis. They accounted for 13.39 per cent of the total variance in weaning weight in the Canadian Corriedales and Rambouillets when all types of birth and rearing were considered. For all three breeds combined year differences accounted for 17.01 and 17.38 per cent of the total variance in weaning weight in singles, and twins raised singly. From the standpoint of selection at weaning time these differences were not extremely important but they emphasize the need for a different correction factor for each year rather than a common factor for all years.

In some instances it would be necessary to compare progeny groups born in different years. Under those circumstances, year differences would be important and to make a fair comparison adjustment should be made for them.

Type of birth and rearing caused differences in weaning weight that were highly significant. Single lambs were heaviest in Rambouillets followed by twins raised singly, and twins raised twin in that order. In Canadian Corriedales the order was reversed for the first two groups, i.e. twins raised singly were the heaviest followed by singles, and twins raised twin. Although the New Zealand Corriedales were not included in the type of birth and rearing analysis due to the small number of twins raised twin it was interesting to note that the order of decreasing weight for the three types of birth and rearing was the

same as for the Canadian Corriedales.

In the two breeds included in the analysis of the effect of type of birth and rearing, this factor accounted for 5.47 per cent of the total variation in weaning weight. This figure is approximately half that reported by Hazel and Terrill (5). The writer of this paper was of the opinion that the disproportionate number of individuals in the subclasses masked the true picture in the analysis and caused the low percentage of total variation. The percentage of total variation due to type of birth and rearing, although low, was of sufficient magnitude to confuse selection at weaning time. Therefore, a method of adjusting for this factor should be evolved.

No attempt was made to determine whether or not selection favored Canadian Corriedale twins raised singly over singles as it favored singles over twins raised singly in the work reported by Phillips and Dawson (8). The possibility that such a favoritism could exist was recognized and further studies on that subject are planned.

Differences in weaning weight due to sire were of significance in one year in each of the two breeds analysed. In 1939 the sire differences in Canadian Corriedales were highly significant and in 1940 the differences in the Rambouillets were significant. On each of these occasions the percentage of total variation due to sires was very high. This would indicate that the sires of the

1939 Canadian Corriedales and the 1940 Rambouillets were more variable genetically than the sires used in these two breeds in other years.

The average percentage of total variation due to sires was 11.20 in the Canadian Corriedales and 5.68 for the Rambouillets over the seven year period. This suggests a greater genetic variability in the Canadian Corriedale sires than in the Rambouillet sires, probably due to the fact that the former is a new breed while the latter is a long-established one. In view of this it would appear that greater care and more rigid selection of sires should be practised in the Canadian Corriedales than in the Rambouillets.

For the purpose of including the third breed, namely New Zealand Corriedales, as fully as possible in the results, analyses were made within types of birth and rearing wherever the number of individuals in the subclasses would permit. In this connection only the twins raised twin were so unevenly distributed that an analysis could not be made.

Breed differences in single lambs of the three breeds were highly significant in singles and twins raised singly accounting for 28.81 and 13.78 per cent of the total variation respectively. It would seem reasonable, in view of the 18.96 per cent of total variation attribut-

able to breed when all types of birth of the two breeds were analysed, to expect that if the number of New Zealand Corriedale twins raised twin would permit analysis the percentage of total variation in the third type of birth would fall somewhere between the two limits reported above. This would indicate the expression of genetic differences in the single lambs and the masking of genetic differences by environment in the twins raised singly.

The differences within type of birth due to years for the three breeds were highly significant in singles, and twins raised singly, accounting for 17.01 and 17.38 per cent of the total variation respectively. Both these figures were somewhat higher than the 13.39 per cent of total variation reported previously due to year differences in the analysis of the two breeds of sheep. Two possible explanations for this difference appeared reasonable, either there was greater variation due to year in the New Zealand Corriedale breed than in the other two breeds, or there was considerably less variation due to year in the type of birth, twins raised twin. The former statement appeared more logical than the latter because sire differences were included with year differences in this breed.

The analyses have shown that differences in weaning weight of ewe lambs were influenced by breed, year, sire, and type of birth and rearing but these factors did

not have equal influence on weaning weights, nor did they have equal practical application to the sheep industry as a whole. Based on the proportion of the total variation in weaning weight these factors in order of importance were breed, year, sire, and type of birth and rearing.

From the practical standpoint the purpose of this study has been to determine the factors that should be considered in improving the selection of future breeding stock, comparing progeny groups, and measuring progress made from year to year. In this flock it has been established that breed differences do exist in weaning weights so selections should be made within breeds for this characteristic, especially if it is desired to maintain these differences.

It also has been established that type of birth and rearing has a significant influence on weaning weight. Therefore, selection simply on weaning weight, without correcting for the effect of type of birth and rearing, would lead to the selection of proportionately more lambs born as singles in the Rambouillets than in the other two breeds and would tend to penalize desirable lambs that might be small simply because of environmental factors rather than genetic factors. Likewise, data not reported in this study show that there are great differences in the proportion of single and twin lambs between sire-progeny groups and

unless correction is made for weaning weight in comparing sires the true value of sires may not be determined.

Two possible methods of nullifying or at least reducing the confusion caused in selection as a result of type of birth and rearing differences present themselves. One method would be to separate the lambs, at the time selection is to be made, into three groups according to type of birth and rearing and the appropriate number of lambs would be selected within each group. The other method would involve the calculation of correction factors, when weaning weights are taken, to adjust the inequalities of type of birth and rearing. These correction factors, calculated in a similar manner to those suggested in the discussion of Table II, page 22, would be applied to individuals within breeds and thus remove bias from selection.

Both methods would involve certain practical difficulties, the former in respect to the amount of handling required to separate the lambs, and the latter from the standpoint of the necessary calculations required to obtain the correction factors. However, although the objections to the latter could be more easily overcome in general practice, either method would serve a very useful purpose in reducing the error in selection.

The fact that significant year differences exist emphasizes the need for correcting for these effects when making comparisons between sire-progeny groups raised in different years or in measuring progress made in a breeding program.

The study reported in this paper is preliminary to a study of other factors that also influence weaning weights and must be considered before a complete set of correction factors for weaning weight can be developed. Some of the factors known or suspected to be important are: sex, birth weight, age of dam, weight of dam, and the milking ability of the dam.

As indicated previously, the disproportionate number of individuals in the subclasses complicated the analysis of the data and led to the elimination of some of the data in some of the analyses. Assistance was sought from a leading authority on statistical methods and for one phase of the analysis an improved method was obtained, but too late to be incorporated in the present material. For other phases of the analysis the application of the method has not been developed. However, the indications are that the significance of the main factors would not be reduced and the validity of the findings would hold. Interactions might assume greater significance than indicated by the methods used. Thus the proportion of total variation due to the various factors might be changed to a certain extent.

SUMMARY AND CONCLUSIONS

The data recorded on the ewe lambs of three breeds of sheep maintained in the Lethbridge Experimental Station flock were analysed to determine the influence of year, breed, sire, and type of birth and rearing on the weaning weight.

Years were an important source of variation in weaning weight. Differences due to this factor were highly significant in all analyses. While not of great importance in selection these differences are an important source of error in sire-progeny group comparisons where the progeny groups are born in different years. These differences emphasize the fact that in designing correction factors they are useful only in the year for which they are designed.

Breed differences in weaning weight were significant in the general analysis of Canadian Corriedale and Rambouillet lambs. In single and twin lambs raised singly of three breeds these differences in weaning weight were highly significant. As selection usually takes place within breeds these differences are not a serious source of error in selection. However, they emphasize the necessity of a separate correction factor for each breed, especially where it is desirable to maintain these differences.

As a source of variation in weaning weight, type of birth and rearing was highly significant. Under usual circumstances, where it is not possible to practise selection or progeny group comparison within type of birth and rearing, these differences are an important source of error. As a result, selection or group comparisons are likely to be biased in favor of the type having the greatest weight. This condition is not conducive to general sheep improvement, and steps should be taken to adjust this source of error in selection or progeny group comparison.

Alternate methods of correction are suggested by (a) limiting selection to type of birth and rearing groups, or (b) designing correction factors for application within breeds to adjust the inequalities of type of birth and rearing.

In general sire differences were not a significant source of variation in weaning weight. However, they did account for a considerable proportion of the total variation and so emphasize the need of selection of sires of uniform and superior quality. It is possible that the sire differences would more nearly approach significance if corrections for type of birth and rearing were made on the data prior to analysis.

The work reported in this paper is preliminary to a study of other factors also influencing weaning weight that must be considered before a complete correction factor for weaning weight can be developed.

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